Team-Level Predictors of Football Injuries in Fifty North Carolina High Schools

By

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Abstract

Background
There is a growing recognition that sports and recreational injuries constitute an important public health problem. They account for more emergency department visits than motor vehicle collisions. The preponderance of these injuries occur in the mid-adolescent years. A dearth of prospective epidemiologic information on sport injury has hampered the development of population-based interventions to prevent sports injury. Risk factors for injury are poorly understood, and most preventive interventions are empirical.

To identify potential risk factors for football injury, this analysis examines injuries in a cohort of fifty North Carolina high school varsity teams. It hypothesizes that certain team-level characteristics are systematically related to variation in injury rates.

Methods
The North Carolina High School Athletic Injury Study (NCHSAIS) surveyed sports injuries in approximately one hundred North Carolina high schools between 1996 and 1999. Twelve girls and boys varsity sports were studied, and each school surveyed six sports. Injuries were expressed as a rate, defined as the number of injuries per $10^5$ athlete-exposures, an exposure being a practice or a game.

To accommodate the team as the unit of analysis in our study, injury rates were expressed as the number of injuries per $10^5$ team-exposures. Univariate statistics are reported as means and proportions. In bivariate analyses, the team injury rate is the continuous dependant variable and the primary outcome of interest. Small sample size and a limited number of team-level variables precluded comprehensive multivariate modeling.

Results
The average injury rate was 411 per $10^5$ exposures among the 50 schools surveying football injuries. The game injury rate, 1566 $10^5$ exposures, was nine times higher than the practice injury rate, 175 per $10^5$ exposures ($p<0.001$). Football coaches had an average of 20 years of experience. Almost all coaches had taken a coaching class and most were certified in cardiopulmonary resuscitation and first aid. There was substantial variation in team injury rates. Inter-quartile injury rates varied by a factor of more than four. The injury rate in the first quartile rate was 169 per $10^5$ exposures, while in the fourth quartile the rate was 739 per $10^5$ exposures.

In bivariate analyses, team size and first aid training of coaches correlated with injury rates. Smaller teams had significantly more injuries than larger teams ($p=0.0026$). The effect of team size in injury rates was very strong in games. Adjusting for the tendency of smaller schools to have smaller teams, the model predicted 420 fewer game injuries per $10^5$ exposures for every additional 10 players ($p=0.0036$). Thirty-three percent of coaches in the highest injury quartile did not have a history of first aid training ($p=0.0011$).

Conclusion
Substantial variation exists in injury rates among football teams. Injuries occur much more frequently in games than practices. Team size and first aid...
training of coaches are predictors of football injuries and may explain some of the variation seen in team rates. Smaller teams have a higher burden of injury than larger teams. Teams with high injury rates are more likely to have coaches without a history of first aid training. These findings suggest strategies for prevention such as insuring adequate team size and promoting the certification of all coaches in first aid. Future research should try to define those factors that make games especially hazardous.

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**Background**

There is growing recognition that sports and recreational injuries are an important public health problem. According to the National Electronic Injury Surveillance System-All Injury Program (NEISS-AIP), emergency department visits due to sports and recreational injuries surpass those caused by motor vehicle collisions.¹ ² Sport is the leading cause of head injury in children.³ ⁴ Sports injuries are estimated to cost $1.6 billion in 1996 dollars.⁵ The largest burden of sports and recreational injuries fall in the mid-adolescent years.¹ Data from the National Center for Catastrophic Sports Injury Research (NCCSI) demonstrate that the incidence of serious injury in collision sports like football hockey and soccer approximates incidence of injury from poisoning, residential fires and bicycling in the adolescent population.⁶ ⁷ Overall injury is the leading cause of morbidity and mortality in children adolescents and young adults⁸ ⁹; yet, the injury literature often does not address sports and recreational injury in its general reviews.⁹ ¹³

The NEISS-AIP and NCCSI provide a broad description of the sports injury problem and permit hazard identification. Methodologic shortcomings, though, prevent these sources from more fully elucidating the sports injury process. Neither collects environmental information in a systematic fashion. They are retrospective and suffer from selection bias. The NEISS-AIP collects data from emergency departments, while the NCCSI relies on voluntary reporting and press reports for information on catastrophic injuries. In addition, these sources
These percentages are a crude index of injury burden and do not reflect the amount of activity in a single sport and the fact that different sports have different practice regimens and game schedules. They cannot be used to make valid comparisons of injuries among sports, genders, and age groups. Such use would be analogous to comparing accidents between private motor vehicles and commercial trucks without taking into account the miles driven by the respective operators. All of these limitations preclude the reliable identification of risk factors and the inferences about causality.

The dearth of prospective epidemiologic data has hampered the development of population-based strategies to prevent sports injury. In North America, few studies have examined risk factors for sports injury prospectively and systematically. Most have provided descriptive information about injury incidence in various sports. There are even fewer studies of interventions to decrease sports and recreational injuries. Without a clear understanding of the athlete and environmental factors that contribute to sports injury, recommendations for improving the safety of sport remain largely “common sense” or empirical.

Models of sports injury are derived from the classic public health model of disease. The multi-factorial model of the sports injury process (Figure 1) depicts a dynamic interaction of the athlete with the environment and the agent of disease. With sports injury, the agent of disease is mechanical energy, or trauma. This model conforms with Haddon’s model of injury control.
research demonstrated that injury and its causal factors behave in a nonrandom fashion. His injury framework conceptualizes risk factors as “agents or vectors” of disease. These risk factors are separate from the injury outcome itself and are amenable to interventions that decrease the likelihood of injury. To promote a systematic approach to injury prevention, Haddon divided the injury process into three stages (the so-called Haddon matrices): the pre-event, the event, and the post-event. The model presented here describes the hypothetical “pre-events” of sports injury and has implications for primary prevention.

Risk factors operate at the athlete or environmental level in the multifactorial model.\textsuperscript{34} Host level factors \textit{predispose} the athlete to injury. Environmental risk factors influence the predisposed athlete, making the individual more or less \textit{susceptible} to injury. Sport is a socially and behaviorally mediated activity, and the sports injury model postulates social and psychosocial, as well as physical, determinants of injury at both the individual and environmental levels.\textsuperscript{35} The multi-factorial model expands on existing models\textsuperscript{34,36} of sports injury, by emphasizing the temporal nature of the sports injury process. It proposes that environmental factors intervene at two points in the temporal sequence of the process. Certain factors modify the risk of injury \textit{remote} from the outcome; others factors intervene \textit{proximal} to outcome. In general, distal factors exert an indirect effect on the probability of injury, while proximal factors play a direct role in determining whether a given instance of trauma will cause injury. For example, an athlete’s level of conditioning may affect susceptibility to injury distal to the outcome, while weather conditions may intervene at the time of
injury. Similarly, the nature of one’s opponents would affect the process proximal to injury.

**Introduction**

All sports share trauma as a necessary agent of disease, but they expose participants to varying intensities and patterns of trauma. Collision sports, like football and soccer, put participants at higher risk for acute musculoskeletal injury, while non-contact sports requiring repetitive movements, like track and field, are more likely to cause overuse injuries.\(^{37,38}\) Thus, different sports will exhibit different risk factor profiles for injury. These profiles will differ at both the athlete and environmental levels. Using conceptual framework of the multifactorial model of sports injury, this study investigates predictors of football injury in a cohort of North Carolina high schools at the environmental level. It focuses on team-level variables that may serve as predictors and potential risk factors for football injury. The study hypothesizes that certain team-level characteristics such as coaching experience, the training of coaches in first aid or CPR, school size, and team size may be systematically related to football injury rates.

**Methods**

The North Carolina High School Athletic Injury Study (NCHSAIS) surveyed sports injuries in approximately one hundred North Carolina high schools over a three-year period from 1996 through 1999. The NCHSAIS studied twelve boys and girls varsity sports; six sports were surveyed in each school. Specific aims of the study were:
To measure the incidence, rate, severity, and etiology of athletic injuries and produce population estimates for the entire state.

To determine the relationship of demographic, exposure, and school size data associated with the occurrence of high school athletic injuries.

To study the relationship of coaches training and years of experience to the occurrence, severity and prevention of injury among high school athletes.

To compare the incidence of injury among female and male athletes in the same or comparable sports.

This analysis explores the second and third aims as they apply to football teams.

The Institutional Review Board of the University of North Carolina School of Medicine approved the research.

The complex survey design of the NCHSAIS has been described in detail elsewhere.\textsuperscript{22, 39} Briefly, schools were selected according to a two-stage, cluster sample design. One hundred were selected from the 324 member schools of the North Carolina High School Athletic Association (NCHSAA). All schools were public except one. In order to insure representative estimates, there were contingencies to substitute for schools that declined to participate and to replace schools that withdrew from the study. At its conclusion, one hundred and nine schools had participated in the study. Fifty public schools surveyed football injuries.

According to the research definition, a reportable injury was one that occurred as a result of participation in a varsity sport and either limited the student’s full participation in the sport the following the day or required medical attention by an athletic trainer, physician, nurse, emergency medical technician, dentist or other health professional. All brain concussions, nerve injuries, eye injuries, and fractures were reportable injuries, regardless of whether they met the above criteria. Injuries were reported as a rate, defined as the number of injuries per
100,000 ($10^5$) athlete-exposures. An athlete-exposure was either a practice or a game.

To accommodate the football team as the unit of analysis, we collapsed athlete-level injury and exposure data by team and generated a team level injury rates for each school. This rate is reported as the number of injuries per $10^5$ exposures. It includes preseason and regular season exposures. Certain continuous variables, such as the number of years a coach played high school or college football, were dichotomized to reflect any history of play at these levels. Because some teams withdrew from the NCHSAIS and were replaced, three years of data was not available on all teams. The analyses did not treat team injury rates for each year as separate observations; rather, rates were averaged over the years that teams contributed data. This strategy avoided problems of intra-school correlation of injury rates and was essentially more conservative. The histogram of school injury rates approximated a normal distribution. In bivariate analyses, the team injury rate served as the continuous, dependent variable and the primary outcome of interest.

The analysis reports summary statistics of team-level variables contained in the NCHSAIS data set. It reports the distribution of variables across injury quartiles. Scatterplots were examined for evidence of linear trend or threshold effects. Bivariate analyses were performed using variables least squares regression and were weighted for total number of exposures. Small sample size and limited number of variables precluded comprehensive multivariate analysis and non-linear modeling. Statistical analyses were performed using Stata 7.0, College Station, Texas.
Results

Fifty teams surveyed football injuries. Eighteen reported injury data for three years; fourteen, for two years; and eighteen, for one year. Table 1 summarizes team injury rates and characteristics of schools, coaches, and teams. The average team injury rate was 411 per $10^5$ exposures. (The average injury rate for all twelve sports in the NCHSAIS was 232 per $10^5$ exposures. Boys soccer had the second highest rate at 305 per $10^5$ exposures, while cheerleading had the lowest rate at 80 per $10^5$ exposures.22) The game injury rate, 1566 per $10^5$ exposures, was almost nine times the practice rate, 175 per $10^4$ exposures (p <0.001). Fourteen schools withdrew from the study; the rate for these teams was 419 per $10^5$ exposures. Withdrawing schools cited the clerical burden of reporting as the principle reason for study withdrawal.22,39

On average, football coaches had twenty years of coaching experience. With one exception, coaches were all male. Almost all were faculty members of their schools, had taken a coaching class, or played high school football. The vast majority had college playing experience, and most had a history of certification in cardiopulmonary resuscitation (CPR) or first aid. The average number of athletes per team was 36; team size did not vary between the preseason and regular season.

Analysis of team injury rates by quartiles demonstrates substantial variation in injury rates between the lowest and highest quartiles (Table 2). The injury rate in the fourth quartile, 738 per $10^5$exposures, is more than four times greater than the rate in the first quartile, 169 per $10^5$exposures. Table 2 also shows the
relationship between team-level variables and injury quartiles. No clear trend between school size and injury rates emerges. Although schools in the highest quartile have 250 more students than schools in the lowest quartile, the difference in enrollment between the third and fourth quartiles is even larger and trends in the opposite direction. The age of coaches and years of coaching experience are higher in the fourth quartile, but the differences are not large. Coaches with a history of CPR certification are evenly distributed among the quartiles.

Examination of the injury quartiles suggests that first aid training and team size may be related to injury. Four out of twelve (33%) of coaches in the highest injury quartile had no history of first aid training. Only two other coaches lacked first aid training, and they were in the first and second quartiles. Injury rates appear to vary inversely with team size. The injury quartiles and scatterplots (See Figures 2 and 3.) demonstrate that injury rates tend to increase as team size decreases. Injury quartiles were re-generated for game and practice rates, and the trends for these two variables persisted (data not shown).

In bivariate analyses, only a coach’s history of first aid certification and team size emerge as statistical correlates of team injury rates (Table 3). The relationship between the number of athletes per team and injury rates is of particular interest. Despite the small sample size, a strong association between smaller team size and higher injury rates exists ($p=0.038$). After adjusting for school size, this relationship becomes stronger ($p=0.0026$). Predictably, larger schools tend to have larger teams. (North Carolina divides schools into four classes according to size: 1A (smallest) through 4A (largest). Class 1A schools
average 32 players per team; Class 2A, 36; Class 3A, 39; and, Class 4A, 38 (p=0.011).

The relationship between smaller team size and higher injury rates is more pronounced in games than practices. Figures 2 and 3 illustrate the relationship between injury rates and team size in game and practice settings, respectively. The figures present the raw data and the predicted linear relationships, adjusted for school enrolment. For every 10 additional players in game situations, the model predicts 400 fewer injuries per $10^5$ exposures ($p=0.0036$). In practice, there would be 51 fewer injuries with the addition of 10 players; this result does not reach statistical significance ($p=0.103$). Combining game and practice exposures, the model predicts 110 fewer injuries per additional 10 players.

On teams whose coach lacks first aid training, bivariate modeling predicts 703 injuries per $10^5$ exposures compared to a rate of 375 injuries per $10^5$ exposures on teams with certified coaches ($p=0.011$). In game situations this relationship becomes 2408 vs. 1463 injuries per $10^5$ exposures ($p=0.028$). The estimates of the association of first aid training with injuries rates are conservative. Two missing values for first aid training were coded as having had training, and coaches who obtained first aid training at any point during the three-year study period were credited with certification.

**Discussion**

This analysis examined team-level variables and football injuries in fifty North Carolina high schools. No previous study of football injuries has prospectively investigated injury outcomes among as many teams and attempted
to define team-level predictors of injury. The analysis documents substantial variation in injury rates among football teams. Two variables emerge as statistical correlates of injury rates and may explain some of this variation: team size and a coach’s history of first aid training. In addition, game injuries are much more common than practice injuries. The game-practice differential replicates an important finding for all sports surveyed in the NCHSAIS and recent results of a survey of “youth league” sports injuries.\textsuperscript{22, 23} Coaching experience does not appear to correlate with team injury rates, but the study may not have had the power to differentiate based on this variable. These findings improve our understanding of potential risk factors for sports injuries and suggest strategies for injury prevention.

Smaller football teams suffer a greater burden of injury than larger teams. The inverse association between team size and injury rates is intuitive and has several explanations. The first is a statistical explanation: players on smaller teams are more likely to play and are thus exposed to more trauma. Increased exposure to trauma increases the likelihood of injury. The NCHSAIS definition of rate was not time-based, and these findings support the common sense notion that increased playing time is related to increased injury rates. High school football players are also exposed to more trauma because, unlike college and professional athletes, they often play on offense, defense, and special teams. They tend to be less familiar with a given position on the field. The consequences of multi-tasking—more exposure to trauma and less specialization—are felt more keenly
on smaller teams and would increase an athlete’s likelihood of sustaining an injury.

Smaller team size may contribute to injury susceptibility by mechanisms other than more trauma exposure and less specialization. Athletes on smaller teams will compete for longer periods of time. Fatigue associated with prolonged competition may put them at greater risk for injury. From a behavioral standpoint, players on smaller teams might ignore less severe injuries out of sense of solidarity. They may continue to play, knowing that their team cannot easily substitute for them. Smaller teams may substitute more inexperienced or less well conditioned athletes for an injured or absent athlete. Coaches and trainers on smaller teams may have a different threshold for recognizing injuries, knowing that their options for replacing players are more constrained. This “small team scenario” demonstrates the multi-factorial model of the sport injury process. A more predisposed athlete (e.g. fatigued) is affected by an environmental factor (small team). This interaction increases the athlete’s susceptibility to injury. Trauma, with or without the intercession of another proximal environmental factor (e.g. field surface, weather), leads to injury.

The striking relationship between team size and injury rates during games yields additional insights into factors that may contribute to sports injury. While practice injury rates vary only modestly in relation to team size, game rates vary substantially and are nine times higher than practice rates. In practice, there is no imperative for competition to proceed with full intensity or in the face of adverse athlete or environmental factors (e.g. fatigue, weather or availability of athletes).
Athletes, coaches and trainers can attenuate the dose and intensity of trauma, and
they can interrupt practice at their discretion. Team size would not be expected to
affect injury rates substantially. The unpredictable, competitive atmosphere of
games prevents teams from controlling a variety of factors, regardless of team
size. In general, games are not suspended due to player fatigue or anything but the
most adverse weather conditions. Smaller teams would find it more difficult to
adapt to adverse game conditions and less able to deploy their resources in a
manner that would promote safety than larger teams.

Other unmeasured factors may explain the relationship between team size
and injury rates. Financially less-advantaged school districts may field smaller
teams due to constraints in resources. These schools may also have fewer
resources to devote to player safety. The NCHSAIS did not collect data on
resource allocation among participating schools. However, the NCHSAA, the
governing body for high school athletics, does have uniform policies to safeguard
athletes in all member schools.\textsuperscript{40} Protective equipment must meet certain
standards. Regulations specify how much conditioning must occur before players
can compete in scrimmages or games. To prevent heat related injuries, there are
guidelines regulating competition in hot weather. In addition, for football alone,
the NCHSAA mandates the presence of a certified trainer or EMT at all practices
and games.\textsuperscript{41} This person may not serve simultaneously in a coaching role. These
policies do not eliminate resource disparity, but adherence to them would mitigate
the effect of disparities as a cause of injuries.

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The statistical association between first aid training and decreased injuries is less easy to explain. The number of untrained coaches was small (six). Yet, the finding that one third of the coaches in the highest injury quartile had no first aid training is compelling. This result held for game injury rates as well. First aid training may be a marker for increased vigilance toward athlete safety and injury prevention. Conversely, one might just as easily hypothesize an association between first aid training and more injuries due to detection bias. The expertise conferred by first aid training might make coaches more likely to detect, respond to, and report injuries. First aid certification for coaches has been advocated to improve safety, presumably at the level of secondary injury prevention (the “event” and “post-event” stages of the Haddon matrices). This study should prompt further research into the role of first aid training in the primary prevention of sports injury.

Most postulated risk factors for sports injury remain uninvestigated. Prospective research has identified age, size of athletes and competitive setting as determinants of injury. In both rugby and American football, injuries occur more frequently as athletes age and grow, presumably because the “dose” of trauma increases with size. Observational studies have linked certain protective equipment to fewer and less severe injuries among bicycle riders, hockey players, in-line skaters, and baseball players. Notably, among cyclists and hockey players, the use protective head and facial equipment was associated with fewer concussions. A few interventional studies have modified hypothetical risk factors directly in an attempt to prevent injuries. Janda et al. demonstrated that
“breakaway” bases in softball games decreased lower leg injuries by 95 percent.\textsuperscript{49} Another study in high school football players tested whether stretching in the post-halftime period decreased injuries; it showed no benefit.\textsuperscript{26}

More prospective research is needed into risk factors for sports injury. Empirical solutions to sports injury prevention are not always effective and some have been counter-productive. Mouth guards almost certainly prevent oral and dental injuries in collision sports, but protective headgear has not been demonstrated to reduce concussion in amateur boxers.\textsuperscript{28, 50, 51} The development of the modern, caged football helmet in the 1950’s exemplifies the limits of empiricism and the need to systematically evaluate prevention measures.\textsuperscript{20} In the decade following its introduction, there was a surge fatal and serious head and neck injuries.\textsuperscript{17} The ostensible protection of the helmet led players to use it as a ram. Starting in the 1970’s, rule changes and educational initiatives aimed at “keeping the head out of football” reversed the trend in catastrophic injuries and let to a decline that persisted into1980’s.\textsuperscript{17, 52}

The identification of risk factors will move sport injury prevention beyond empirical solutions and will allow systematic approaches to the problem. Experts in the epidemiology of sports injury advocate public health surveillance as a way to advance science and promote prevention.\textsuperscript{18, 21, 23, 36, 53, 54} The \textit{sports injury sequence of prevention}, proposed by Van Mechelen et al., addresses both of these priorities.\textsuperscript{36} It has four steps:

- The description of the sports injury problem.
- The establishment of the etiology and mechanism of injury
- The introduction of preventive measures based on the previous steps.
- The evaluation of the effectiveness of these measures and the refinement and repetition of the preceding steps.
This surveillance sequence resembles models of continuing quality improvement that have been adopted in public health, clinical, and commercial settings.\textsuperscript{55-59} The credibility and long-term success of surveillance systems will depend on community support, especially for an activity with as much cultural resonance as sport. It’s development and implementation must take into account the socio-cultural context and actively enlist the support of leaders like coaches and trainers.\textsuperscript{60}

For epidemiologic and organizational reasons, football is an ideal target for the prevention sequence. The sport has the highest participation (1.02 million high school players)\textsuperscript{61} and the highest injury rate of all sports, and thus the greatest burden of potentially preventable disease. In addition, high school football has a well-developed infrastructure and a commitment to safety that would facilitate systems interventions.\textsuperscript{62} Coaches and trainers should be informed of the relationship between team size and injury. This research should not lead to mandated team sizes or indiscriminate efforts to increase team size. It would be counter-productive if less-skilled or less-willing players competed to fulfill an arbitrary team size; however, knowledge of the relationship between team size and injury rates could prompt coaches to field teams with as large a number of qualified players as possible in order to mitigate risk. Coaches and trainers will not be surprised to learn that game injuries occur more frequently than practice injuries. The magnitude of this difference, though, may surprise them. This study should reassure team that their efforts to promote safety in practice are effective but that games may require greater vigilance to prevent injury. Moreover,
identifying the determinants of game injuries should be a priority for future research.

The NCHSAIS did not collect data examining whether disparities in resource allocation accounted for differences in team size and injuries rates. Coaches and trainers, though, are in the best position to judge the adequacy of resources. If they feel that inadequate resources prevent them from fielding a competitive team of sufficient size, they can raise this as a safety issue. With regard to first aid training, organizations with regulatory authority like the NCHSAA and its parent group, the National Federation of State High School Associations, could expand their commitment to safety by supporting the certification of all coaches in first-aid. Although eighty-eight percent of football coaches in the NCHSAIS were certified in first aid, the figure for all sports was only thirty-three percent. 22

This study has several limitations. The sample size of 50 schools and the number of team-level variables are relatively small. This restricts multivariate modeling of environmental risk factors and the assignment of causality. In spite of the modeling limitations, the findings of this study are more robust than they would have otherwise been because the NCHSAA safety regulations control for several factors presented in the multi-factorial model of injury. A second limitation is that the NCHSAIS only studied varsity athletes. These well-conditioned, elite athletes compete in a structured, safety conscious environment. The results of this study may not apply to junior varsity athletes or to athletes participating in “pick-up,” intra-mural or recreational settings. It is plausible that
team size and first aid training would become more powerful predictors of injury rates in these less organized settings. Because private schools were not represented in the sample, the results may not generalize to this setting.

The results also suggest limitations in the research definition of exposure. The non-time-based measure of exposure does not capture the duration or intensity of an athletic exposure. As a research tool, precise monitoring of an athlete's playing time would be intrusive and probably not feasible. Clearly, the duration of exposure to trauma will vary among sports with discontinuous play, like football, and sports with continuous play, like soccer. This would pose a major methodological dilemma if different sports shared the same risk factors. Since risk factor profiles for injury are likely to be sport dependant, the research definition of exposure is valid for comparisons within a sport. (Moreover, the results suggest that team size is an indirect measure of playing time; as such, the reciprocal of team size could serve as a statistical proxy when a time measure of exposure is not feasible.)

A major limitation of the NCHSAIS and other studies is that they do not characterize behavioral and psychosocial risk factors related to the sports injury. In the multi-factorial model of the sports injury process, these factors operate at the athlete and environmental level. Historical evidence suggests their importance and shows that they are amenable to change. In the early 20th century, numerous on the field deaths caused by rough play jeopardized football's existence. Direct intervention by President Theodore Roosevelt led to rule changes that modified the behavioral milieu of the sport, making it less violent, safer, and more
The results of this study suggest a hypothesis that the dramatic difference in injury rates between practices and games results in large part from the emotional and adversarial dynamic that prevails in game settings. The elucidation of the psychosocial determinants of sports injury should be a priority for future research.

Conclusions

Sports injury is an important cause of morbidity in children, but its epidemiology and causality are not well understood. Risk factors for sports injury occur at the athlete and environmental levels. Individual sports exhibit their own risk factor profiles. The NCHSAIS provides insights into the environmental risk factor profile for football injuries. Team size and first aid training of coaches appear to be important determinants of team injury rates and probably act through indirect mechanisms. Game injuries are many times more common than practice injuries. Together these findings suggest strategies for prevention and new avenues of research.

The well-organized and safety conscious milieu of high school football lends itself to solutions that borrow from the public health model of disease and combine research, evaluation, and prevention. Future research should prioritize the identification of factors that make athletes much more susceptible to injury in games than in practices. Many of these are likely to be psychosocial.
References


44. Benson BW, Mohtadi NG, Rose MS, Meeuwisse WH. Head and neck injuries among ice hockey players wearing full face shields vs half face shields. *Jama.* 1999;282(24):2328-2332.


Figure 1. Multi-Factorial Model of The Sports Injury Process

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<td># Practices or Games</td>
<td>Opponents</td>
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<td>Conditioning Requirements</td>
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Team-Level Predictors of Football Injuries in Fifty North Carolina High Schools
Figure 2. Predicted Game Injury Rates By Team Size (Adjusted for School Enrolment)

Figure 3. Predicted Practice Injury Rates By Team Size (Adjusted for School Enrolment)

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Team-Level Predictors of Football Injuries in Fifty North Carolina High Schools
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<th>S.D. (Range)</th>
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<td>230 (0-1184)</td>
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<td>1566 956 (0-3409)</td>
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**Head Coach Characteristics**

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**Athletes Per Team**

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<thead>
<tr>
<th>Variable</th>
<th>Number/Average (Range)</th>
<th>S.D. (Range)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Games</td>
<td>96 (0-3409)</td>
<td>96 (0-3409)</td>
</tr>
<tr>
<td>Practices</td>
<td>175* 144 (0-413)</td>
<td>144 (0-413)</td>
</tr>
<tr>
<td>School Size</td>
<td>921 356 (285-1835)</td>
<td>356 (285-1835)</td>
</tr>
</tbody>
</table>

*P-Value <0.001 for difference between game and practice injury rates

**Table 2. Quartile Injury Rates & Team Variables**

<table>
<thead>
<tr>
<th>Variable</th>
<th>First (n=13)</th>
<th>Second (n=12)</th>
<th>Third (n=13)</th>
<th>Fourth (n=12)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Injuries/10^5 Exp. (Range)</td>
<td>169 (0-232)</td>
<td>292 (236-359)</td>
<td>448 (364-585)</td>
<td>738 (610-1184)</td>
</tr>
<tr>
<td>School Size</td>
<td>913</td>
<td>1018</td>
<td>759</td>
<td>1172</td>
</tr>
<tr>
<td>Age of Coach</td>
<td>44</td>
<td>42</td>
<td>45</td>
<td>47</td>
</tr>
<tr>
<td>Years High</td>
<td>19</td>
<td>18</td>
<td>20</td>
<td>23</td>
</tr>
<tr>
<td>School Coaching</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>No First Aid Certification (%)</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>No CPR Certification (%)</td>
<td>-7.55</td>
<td>.038</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Athletes/ Team</td>
<td>46</td>
<td>38</td>
<td>32</td>
<td>37</td>
</tr>
</tbody>
</table>

**Table 3. Bivariate Analysis of Injury Rates Using Least Squares Regression**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Beta-Coefficient</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>School Size</td>
<td>.138</td>
<td>.117</td>
</tr>
<tr>
<td>Age of Coach</td>
<td>3.40</td>
<td>.234</td>
</tr>
<tr>
<td>Years High School Coaching</td>
<td>3.01</td>
<td>.272</td>
</tr>
<tr>
<td>Coach with College Play</td>
<td>-66.8</td>
<td>.397</td>
</tr>
<tr>
<td>History of First Aid Certification</td>
<td>-328</td>
<td>.0011</td>
</tr>
<tr>
<td>History of CPR Certification</td>
<td>49.6</td>
<td>.587</td>
</tr>
<tr>
<td>Athletes per Team</td>
<td>-7.55</td>
<td>.038</td>
</tr>
<tr>
<td>Adjusted for School Size</td>
<td>-11.04</td>
<td>.0026</td>
</tr>
<tr>
<td>Games Only</td>
<td>-40.6</td>
<td>.0033</td>
</tr>
<tr>
<td>Practices Only</td>
<td>-5.13</td>
<td>.104</td>
</tr>
</tbody>
</table>

Paul R. Chelminski, MD
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